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The role of environmental values, socio-demographics and building characteristics in setting room temperatures in winter

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ABSTRACT

To promote a sustainable energy transition, it is important to encourage energy conservation by various actors including households. Strategies to promote energy savings will be more effective if they target key factors that affect behaviour associated with a high energy demand. Space heating is responsible for a substantial proportion of overall household energy use. This study investigated which variables are related to room temperature settings as a key behaviour influencing gas use in households. Extending previous research, we examined to what extent three different types of variables are related to temperature settings in the living room during day time and night time, namely buildings' physical characteristics, socio-demographics, and psychological factors. Results of a large-scale questionnaire study among 1461 Dutch households showed that age of the respondent, number of inhabitants in the household, the year of construction of the house and biospheric values were strongly related to room temperature settings during day time. Room temperature settings during night time were particularly related to the year of construction and biospheric values strength. Our results demonstrate that integrated approaches enhance our understanding of factors influence household gas use. Theoretical and practical policy implications of these findings are discussed.

1. Introduction

The energy demand in the Netherlands heavily relies on the use of fossil fuels. Data on energy consumption in the Netherlands show that natural gas is the primary source of energy consumption, which made up 40% of the country's energy consumption in 2016 [1]. In total, natural gas consumption levels were above 30 billion cubic meters per year, for the years 2005–2015 [2]. A substantial proportion of natural gas is consumed by households, particularly for home heating. In particular, household consumption for heating purposes made up 87% of the total natural gas consumption of households in the Netherlands [3]. Natural gas usage causes environmental problems including greenhouse gas emissions that contribute to climate change [4], which has been a major concern to governments and the public. These problems can be reduced if households would reduce their gas consumption [5–8]. Reducing gas consumption to reduce greenhouse gas emissions will be important to mitigate climate change and is, therefore, a pertinent priority.

Despite the importance of household gas consumption, most research has been focused on determinants factors of other energy sources and mainly on electricity consumption while gas use has been understudied. In particular, there are a very few studies have attempted to explicitly examine household gas-use behaviour. Therefore, an improved understanding of factors influencing household gas-use behaviour is critical to design policies to effectively tackle these issues. This requires a more in-depth assessment of factors influencing gas consumption behaviour, and particularly behaviour that substantially contributes to households' gas consumption, such as home heating. To address this issue, we aim to study factors affecting room temperature settings in households. Many factors may affect room temperature settings in households, including contextual factors, such as building characteristics, socio-demographic variables and psychological factors (e.g. the values endorse), can explain room temperature settings in dwellings. As yet, these factors are typically studied in isolation, providing limited insights into the unique effects and relative importance of different factors influencing room temperature settings in

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households. A comprehensive overview of relevant factors influencing gas consumption behaviour is critical to develop policy to reduce gas use, as policy aimed to reduce household gas use will be more effective when it targets key predictors of gas use. Notably, rather different policy strategies would be called for, depending on whether building characteristics, socio demographics, or psychological factors would particularly predict household gas use, ranging from improving energy efficiency in buildings to enhancing motivation to reduce gas use via, e.g., educational and informational campaigns. To address this gap in the literature, and extending previous research [8–15], we assessed to what extent building characteristics, socio-demographic variables and psychological factors simultaneously can explain room temperature settings in dwellings.

1.1. Impact of building characteristics on room temperature settings

Regarding the likely impact of building characteristics on room temperature settings, one important factor may be the year of construction. Because older houses are typically less well insulated and are oftentimes not draught proof, it may be difficult to heat this type of houses to a comfortable temperature, which may cause households to set the temperature higher than in houses that are well insulated [12]. Therefore, the year of construction may influence room temperature settings. Yet, on the other hand, a study has found that inhabitants of houses built after 1970 put the temperature on average 3 °C higher than inhabitants of houses built before 1914 [16]. Moreover, another study was reported that, from a heating demand perspective, US residential buildings constructed from the 1940s perform better than those built from the 1980s [14]. An explanation could be that buildings constructed after 1970s were not designed to provide comfort standards that also fulfil the current (i.e. 2000s onward) energy-efficiency standards. Swedish researchers found that inhabitants of buildings built before 1980 put the temperature higher only when they have electricity heating, but not when gas heating is in place [17]. Hence, contradictory findings have been reported in the literature. Therefore, this study examines whether and how the year of construction of Dutch buildings affects room temperature settings.

Another factor that may affect room temperature settings is the type of residence. The most common dwelling types in the Netherlands are detached houses, semi-detached houses, terraced houses and apartments. Detached house refers to a free-standing residential building. Semi-detached house is a type of detached house that share one common wall with the next similar building. The most common type of dwelling in the Netherlands are terraced houses that are two or three stories high and adjoined by two, three or more identical houses. Apartments refer to multi-family houses in one building, mostly located at different stories. Type of building could affect indoor temperature settings. For example, in UK dwellings, the lowest daily average indoor temperature setting in winter was found for terraced houses, maybe because these type of dwellings are typically occupied by single or two people only [15]. Another explanation may be that terraced houses are surrounded by other heated dwellings, so that the dwelling may feel warmer. Hence, building characteristics can have an important impact on room temperature settings.

1.2. Impact of socio-demographic variables on room temperature settings

A second relevant type of factors that might influence room temperature settings are social-demographic variables. The age of occupants can influence indoor temperature settings. On the one hand, elderly people are more keen on conserving energy and often have lower temperature settings than average [13,18]. However, on the other hand, elderly people have a lower body temperature and therefore prefer a higher room temperature than younger people. Indeed, older households seem to prefer to set a higher indoor temperature, particularly when the oldest person is over 74 years old [19].

The number of people in the household could also impact indoor temperature settings of the dwelling and is positively correlated with gas consumption [10]. Furthermore, the presence of children in a household can be associated with setting higher indoor temperatures in winter. For example, the presence of one child less than 12 years old has a significant effect on heating requirements, with indoor temperatures of more than 4 °C higher compared to households with no children in Chinese dwellings [11]. Similarly, the presence of a child under 5 years old increased the mean indoor temperature compared to households without children, and the number of children under 18 years old increased indoor temperature settings in English residences [19].

A meta-analysis on thermal comfort and gender found that females are more likely to show thermal dissatisfaction than males as they are more sensitive to lower indoor temperatures [20]. This implies that room temperature settings may be higher as the number of females increases in households. Yet, some studies found no effect of gender on indoor temperature settings [21–23]. Therefore, the effect of socio-demographic variables can play an important role in room temperatures setting.

1.3. Impact of psychological variables on room temperature settings

Room temperature settings may also be influenced by psychological factors, notably motivational factors. One relevant type of motivational factor are values, that reflect desirable and trans-situational goals that serve as guiding principles in individual's life [24]. Values are abstract, general and maintain relatively stable over time [25]. Research on environmental behaviour suggests that four type of values are particularly related to environmental behaviour such as home energy consumption behaviour [26–28]: biospheric values (i.e. emphasizing protecting the environment), egoistic values (i.e. focusing on self-interest), altruistic values (i.e. reflecting concern for other people) and hedonic values (i.e. focusing on doing pleasant things and reducing effort). Generally, people with strong altruistic and particularly biospheric values are more likely to engage in pro-environmental behaviour, including behaviours that would reduce gas use [27,29]. Strong egoistic and hedonic values are often negatively related to pro-environmental behaviours, possibly because such behaviours can be associated with more efforts and costs [30,31]. These four types of values appear to affect a range of environmental behaviours, and may therefore also affect room temperature settings. Yet, to our knowledge, the relationships between values and room temperature settings have not been studied yet. We therefore, in this study examined whether and to what extent these values are related to room temperature settings as well.

1.4. Aim of this paper

In this study we aimed to study to what extent the factors discussed above are related to room temperature settings in residential buildings with gas-fuelled space heating in the winter in the Netherlands during day time and night time. We first investigated room temperature settings during day time and night time for different residence types. Second, we examined the bivariate correlations between the three types of predictor variables and room temperature settings during day time and night time in the most common residence type, namely terraced house. Third, we examined the unique relationships between building characteristics, socio-demographic and psychological factors and room temperature settings during day time and night time.

2. Materials and methods

2.1. Procedure and sample

A questionnaire survey that was part of the project “Psychological, social and financial barriers to energy efficiency” (PENNY, see http://www.penny-project.eu/) was used. This was an online questionnaire study that was conducted among clients of a Dutch energy company, Qurrent, in the Netherlands in May 2017. Data were collected on building variables, socio-demographic characteristics, psychological variables and room temperature settings. The questionnaire was administered online, and filled out by 2318 respondents. Data on room temperature settings at day and night time, our dependent variable, were available for 2110 households. Of these 2110 households, 649 were excluded from the sample based on two exclusion criteria:

(1) When they answered “don't know” to the following questions: “what is the usual temperature in your living room during winter at day time and night time in winter?”, “in which of the following periods was your house originally built” and “what energy source do you primarily use for space heating”, as this information is key to address our research questions. In total 153 cases were excluded.
(2) When the main energy source for heating the residence was not gas. This was done as our main focus was on gas use for space heating. In total 496 cases were excluded.

Therefore, the total final sample size included 1461 households, which formed the basis for all the analyses carried out in this study.

2.2. Questionnaire

The questionnaire included questions on building characteristics, socio-demographic variables, values, and room temperature settings during day time and night time. Tables 1–3 include an overview of the building characteristics, socio-demographic and values covered, including the abbreviation of the variable names that were used when reporting the results in Fig. 2.

2.2.1. Building characteristics

Respondents were asked to indicate the type of dwelling they live in (i.e. detached house, semi-detached house, terraced house, or apartment in a multi-family house) and the year of construction of the dwelling. Table 1 shows the building-specific variables that were included and their response percentages; 18.3% of the participants lived in a detached houses, 19.4% in a semi-detached houses, 42% in a terraced houses, and 20.3% in an apartments. We considered these as categorical variables, and used dummy variables for residence types that represent subgroups of the sample in our study. Four categories were provided to measure the year of construction of the houses; Table 1 shows that most houses were built between 1971 and 2000 (38%).

Table 1
Descriptives for building variables (%; bold = reference category).

Variable (abbreviation)	Response categories (percentage)
Residence type (residtype)	Detached (18.3%), semi-detached (19.4%), terraced (42%), **apartment (20.3%)**
Year built (built)	**Before 1940 (26.4%),** 1940–1970 (18.4%), 1971–2000 (38%), 2001 or later (17.2%)

Table 2
Descriptives for socio-demographic variables (%; bold = reference category).

Variable (abbreviation)	Response categories (percentage)
Number of children in household (child)	**None (58.8%),** 1 (16.2%), 2 (17.7%), 3 (6.2%), 4 or more (1.1%)
Number of females in household (females)	**None (10.3%),** 1 (60.8%), 2 (18.4%), 3 (8.2%), 4 or more (2.3%)
Number of males in household (males)	**None (11.8%),** 1 (58.9%), 2 (18.2%), 3 (9%), 4 or more (2.1%)
Respondent age (age)	(Continuous: M = 50.16, SD = 14.33, Min = 19, Max = 85)

Table 3
Descriptive for the four types of values.

Variable (abbreviation)	Cronbach's alpha	M (SD)	Min	Max	Range
Biospheric values (VBio)	.86	5.17 (1.27)	-.75	7.00	7.75
Egoistic values (VEgo)	.74	1.94 (1.23)	−1.00	6.40	7.40
Hedonic values (VHed)	.82	4.62 (1.38)	.00	7.00	7.00
Altruistic values (VAlt)	.76	5.14 (1.18)	.00	7.00	7.00

2.2.2. Socio-demographic variables

In total 531 females and 930 males participated in the study. Age ranged from 19 to 85 (M = 50.16, SD = 14.33). We additionally inquired about the number of children up to 19 years, the number of females and males in the household, and age of the respondents (see Table 2). The number of children, females and males in house were categorised into 5 categories with “none”, “1”, “2”, “3”, “4 or more”. In most households, no children were present (58.8% of the sample). In 60.8% of the households, only one female was present in the household, which was the largest proportion, while less than 3% of households comprised of four or more females. Similarly, most households comprised only one male (about 59% of the sample), and around 2% had four or more males in the household. The “none” category mentioned in the dataset was considered as a reference category in the analyses.

2.2.3. Values

Respondents filled out a value questionnaire including 16 values reflecting biospheric, egoistic, hedonic and altruistic values [27]. Behind each value a brief explanation was given of the relevant value. Biospheric values were measured by four items namely: respecting the earth: harmony with other species; unity with nature: fitting into nature; protecting the environment: preserving nature; preventing pollution: protecting natural resources. Altruistic values orientation were measured with four items as well, notably equality: equal opportunity for all; a world at peace: free of war and conflict; social justice: correcting injustice, care for the weak; helpful: working for the welfare of others. Egoistic values were measured with five items, namely social power: control over others, dominance; wealth: material possessions, money; authority: the right to lead or command; influential: having an impact on people and events; Ambitious: hardworking, aspiring. Hedonic values were measured with three items, notably pleasure: joy, gratification of desires; enjoying life: enjoying food, sex, leisure, etc.; self-indulgent: doing pleasant things.

Participants indicated to what extent these values were important to them as a general goal in their life, on a 9-point scale ranging from −1 = opposed to my values, 0 = not important, 3 = important to 7 = extremely important. Following Schwartz [24,32], respondents were advised to distinguish as much as possible between the scores by crossing different numbers and to rate no more than two values as extremely important. The biospheric value items formed a reliable scale (Cronbach's alpha .86; M = 5.17, SD = 1.27). The internal consistency of the egoistic value scale was 0.74

Table 4
Descriptives for room temperature settings during day and night time, respectively, across resident types (n = 1461).

Room temperature	Day time		Night time	
	frequency	percentage	frequency	percentage
Below 16 °C	37	2.5%	497	34%
16 °C	34	2.3%	373	25.5%
17 °C	61	4.2%	259	17.7%
18 °C	205	14%	164	11.2%
19 °C	383	26.2%	71	4.9%
20 °C	493	33.7%	64	4.4%
21 °C	202	13.8%	20	1.4%
22 °C	40	2.7%	9	.6%
23 °C	6	.4%	4	.3%

(M = 1.94, SD = 1.23). The items of the hedonic value formed a reliable scale too (Cronbach's alpha .82, M = 4.62, SD = 1.38). The internal consistency of the altruistic value scale was 0.76 (M = 5.14, SD = 1.18). Thus, all values had sufficient internal consistency.

2.2.4. Dependent variable: room temperature settings
Respondents indicated the usual temperature in their living room during day time and night time, respectively, in winter, measured in degrees Celsius. Responses were classified into 11 categories ranging from 1 = below 16 °C to 11 = above 24 °C. Category 10 and 11 were chosen by none of respondents. These categories were, therefore, excluded from the analysis. As a consequence, the dependent variable consisted 9 categories. Table 4 shows the frequencies and percentages of respondents for these 9 categories of temperature during day time and night time. The largest proportion of the sample reported room temperature settings during day time to be 20 °C degree, while the room temperature settings during night time was mostly below 16 °C.

2.3. Data analyses

In a first step, we used the Amelia package for imputation of the remaining missing data for some independent variables [33]. The advantage of using this package among other possible approaches such as Monte Carlo simulation is the speed of implementation using a bootstrapping approach, known as expectation-maximization with bootstrapping (EMB) algorithm. It can handle large number of variables and is suitable to use with large datasets. The Amelia package uses multiple imputations that involve imputing m values for each missing cell in a data matrix and creating m “completed” data sets. In our case, we allocated $m = 3$ as the rate of missing values was 15%.

We used ordinal logistic regression analysis that allows us to use ordinal levels of measurement. Specifically, as the dependent variable was ordinal and was in discrete categories of ascending order, a Proportional Odds Model (POM) was performed [34]. Wide applicability and intuitive interpretation of the POM are two reasons for it being considered the most popular model for ordinal logistic regression. The original coefficients in proportional odds model are given in units of ordered logits, or ordered log odds. To ease interpretation of the logistic regression model, we converted coefficients into odds ratio (OR) (i.e. inverse log of the estimated coefficients).[1] The model was fit using the polr function (“polr” stands for Proportional Odds Logistic Regression) from the MASS package [35] in R [36].

For a POM to be valid, the assumption that all the logit surfaces are parallel must be tested. A nonsignificant test is taken as evidence that the logit surfaces are parallel and that the odds ratios can be interpreted as constant across all possible cut points of the outcome. The “brant” command provides the results of the Brant test of parallel proportional odds assumption for the model. A none-significant omnibus test indicates that there is no evidence the proportional odds assumption is violated. In order to evaluate the goodness of fit of the POM, we calculated Nagelkerke's R squared by the “orm” command that reflects the explained variance of the model. Appendix A provides a more detailed explanation of POM.

3. Results

3.1. Room temperature in different residence types

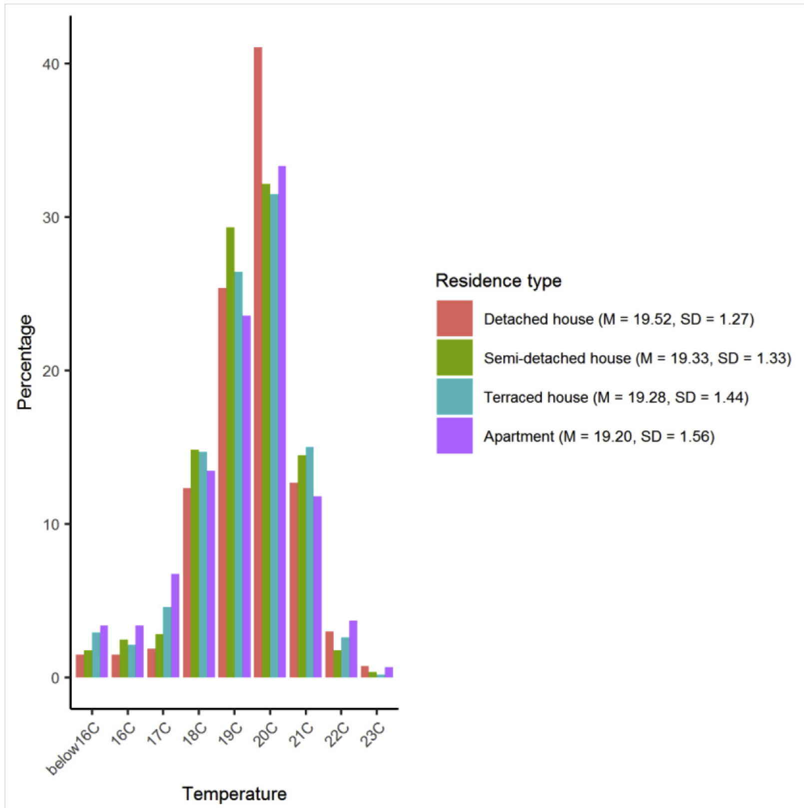
Table 4 shows the frequencies and percentages of each category of room temperature setting during day time and night time across residences types. Across residence types, room temperature during day time was mostly set at 20 °C (33.7%), or 19 °C (26.2%). During night time, they set the room temperature mostly below 16 °C (34%) while 25.5% set their room temperature during the night at 16 °C.

Fig. 1 displays the room temperature settings at day time (a) and night time (b) in different residence types. Fig. 1 (a) shows that 41% of the households in detached houses set their room temperature at 20 °C during the day, which was the largest proportion compared to the other three residence types. Households living in apartments and detached houses were relatively more likely to set the temperature higher (22 °C and 23 °C) during day time. Fig. 1 (b) indicates that 38% of the households living in terraced houses set their room temperature below 16 °C during night time. This implies that those living in terraced houses were more likely to set the room temperature below 16 °C during night time compared to the other three residence types, while none of them set room temperature higher than 22 °C during night time. Detached houses and apartments had the largest proportion of households setting higher room temperatures during night time, at 22 °C and 23 °C, respectively.

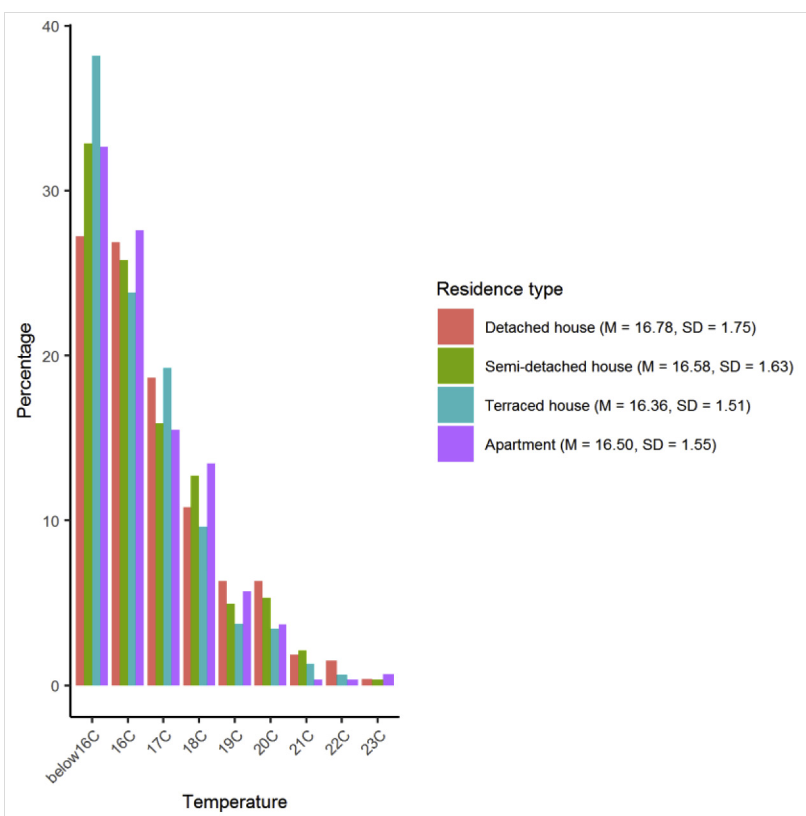
3.2. Correlation between predictor variables and room temperature settings at day time and night time for terraced houses

We examined the correlation between predictor variables and room temperature settings for all four types of residences. As the patterns of correlations across residence types were very similar, we only display and discuss results for terraced houses, which is the most common residence type in our sample. Fig. 2 displays the correlations between the predictors and room temperature settings at day time (a) and at night time (b) for the 613 households living in terraced houses. Notably, correlation coefficients are coloured according to the direction of the relationships. Positive correlations are shown in blue and negative correlations in red. Colour intensity and the size of the circle are proportional to the strength of the correlation coefficients. The variables that most strongly correlated with room temperature settings during day time (a) for terraced houses were: biospheric values (negative correlation), and number of females, males and children in the residence (positive correlation). Year of construction, egoistic values and age were weakly and positively related to room temperature settings at day time, while the relationships with hedonic and altruistic values were very weak almost not statistically significant. This implies that stronger biospheric values are associated with lower room temperature settings at day time for terraced houses, while a greater number of females, males and children in a household implies that room

[1] The e^{β} represents the cumulative odds ratio: the odds of “at least k” under two different conditions. However, the odd ratio is constant across each split, hence it is named Proportional Odds Model.

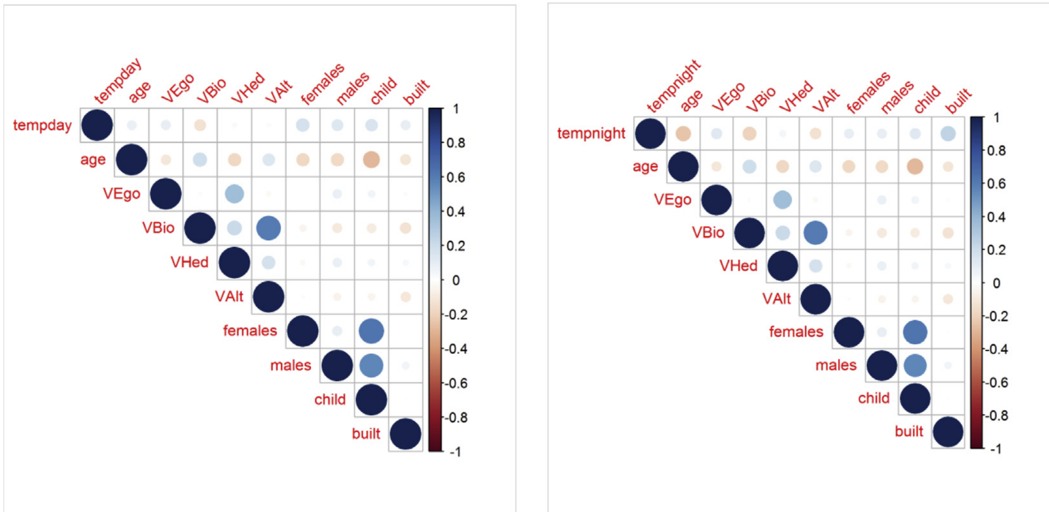


(a)



(b)

Fig. 1. Room temperature settings during day time (a) and night time (b) for each type of residence (%).



(a) *(b)*

Fig. 2. Bivariate correlations between room temperature settings, building characteristics, socio-demographic variables and values for terraced houses at day time (a) and night time (b).

temperature settings during day time are higher for terraced houses. Besides, the older the respondents and the stronger one's egoistic values, the higher room temperature settings during day time, but these relationships are weaker. Similarly, newer buildings are associated with higher room temperature settings during day time for terraced houses.

For room temperature settings during night time (b), the strongest significant relationships were found for age, biospheric values and the year of construction. Age and biospheric value were negatively related to room temperature settings during night time, suggesting that the older the respondents and the stronger their biospheric values, the lower their temperature settings during night time. We found a positive relationship between the year of construction of the house and room temperature settings during night time, suggesting that the newer buildings have the higher room temperature settings during night time for terraced houses. The number of females, males and children in the household and egoistic values were positively related with room temperature settings at night time, suggesting that the more inhabitants are present in a household and the stronger one's egoistic values have the higher room temperature settings during night time for terraced houses. Altruistic values were weakly and negatively related with room temperature settings at night time in terraced houses, suggesting that people with stronger altruistic values have lower room temperature settings. Hedonic values were hardly related to room temperature settings during night time for terraced houses.

3.3. *Explaining room temperature settings during day time*

Table 5 shows the results of the Proportional Odds Model including the building characteristics, socio-demographic and values as predictor variables, and room temperature settings at day time as dependent variable.[2] The model explained 14% of the variance in room temperature settings during day time. The log likelihood ratio Chi-Square test, $\chi^2_{(23)} = 190.03$, $p < .001$, indicates that the model with these predictors provided a better fit than the null model with no independent variables in predicting cumulative probability for room temperature settings. Age of the respondent, biospheric values, egoistic values, altruistic values, hedonic values, number of females in the household, number of males in the household, residence type and year of construction were significant predictors of room temperature settings during day time. Stronger biospheric values, detached houses, semi-detached houses and terraced houses were associated with lower room temperature settings, while higher age, stronger egoistic values, stronger altruistic values, stronger hedonic values, more females, more males and newer buildings were associated with higher room temperature settings. Specifically, for one unit increase in age, the odds of a higher room temperature settings was 1.035 times greater, after controlling for the effects of the other variables (OR = 1.035, $p < .001$). For one unit increase in biospheric value strength, the odds of a higher room temperature settings was 0.726 times lower, given the effects of other predictors were held constant (OR = 0.726, $p < .001$). The odds of setting room temperature higher was 1.112 times greater when egoistic values increased with one unit, after controlling for the effects of the other variables (OR= 1.112, $p < .05$). For one unit increase in altruistic values, the odds of a higher room temperature settings was 1.163 times greater, given the effects of other predictors were held constant (OR= 1.163, $p < .01$). The odds of a higher room temperature settings was 1.145 times greater when hedonic values increased with one unit, after controlling for the effects of the other variables (OR= 1.145, $p < .01$). Next, the odds of a higher room temperature settings when one female lived in house was 1.971 times greater than when there is no female in the house, given the effects of other predictors were held constant (OR = 1.971, $p < .001$). When there were two females in house, the odds of a higher room temperature settings was 2.731 times (OR = 2.731, $p < .001$) greater, and when there were three females in the house the odds was 3.230 times (OR = 3.230, $p < .001$) greater than when there was no female in the house, given the effects of other predictors were held constant. The odds of a higher room temperature settings when four females or more lived in house was 3.331 times greater than when there was no female in

[2] The Brant test of parallel regression assumption for room temperature settings at day time yields $\chi^2_{(161)} = 98.032$ ($p > .99$), indicating that the proportional odds assumptions for the model was confirmed. This suggests that the effect of all the variables, were constant across separate binary models fit to the cumulative cut points.

Table 5
Results for the Proportional Odds logistic regression Model (POM) for room temperature settings during day time including building characteristics, socio-demographic variables and values as predictor variables. *$p < .05$; **$p < .001$; ***$p < .001$.

Variable	Estimate	SE	OR (95% CI)	*t*-value	*p*-value
Age respondent	.034	.004	1.035 (1.026; 1.043)	8.097	<.001***
Biospheric values	-.319	.052	.726 (.654; .805)	−6.041	<.001***
Egoistic values	.106	.044	1.112 (1.019; 1.214)	2.383	.017*
Altruistic values	.151	.054	1.163 (1.044; 1.295)	2.756	.006**
Hedonic values	.135	.042	1.145 (1.053; 1.245)	3.189	.001**
Number of females (Ref = none)					
Number of females = 1	.678	.177	1.971 (1.391; 2.794)	3.818	<.001***
Number of females = 2	1.004	.237	2.731 (1.715; 4.354)	4.230	<.001***
Number of females = 3	1.172	.325	3.230 (1.710; 6.127)	3.605	<.001***
Number of females = 4 or more	1.203	.497	3.331 (1.257; 8.890)	2.416	.016*
Number of males (Ref = none)					
Number of males = 1	.766	.161	2.151 (1.568; 2.951)	4.753	<.001***
Number of males = 2	.654	.213	1.924 (1.266; 2.926)	3.064	.002**
Number of males = 3	.851	.288	2.342 (1.329; 4.126)	2.947	.003**
Number of males = 4 or more	.798	.497	2.222 (.836; 5.912)	1.606	.108
Number of children (Ref = none)					
Number of children = 1	.105	.184	1.111 (.774; 1.595)	.572	.567
Number of children = 2	.275	.223	1.317 (.850; 2.042)	1.234	.217
Number of children = 3	-.533	.350	.586 (.294; 1.166)	−1.520	.128
Number of children = 4 or more	.342	.573	1.407 (.452; 4.313)	.596	.551
Residence type (Ref = apartment)					
Detached house	-.453	.187	.635 (.439; .916)	−2.422	.015*
Semi-detached house	-.461	.178	.630 (.443; .894)	−2.581	.010*
Terraced house	-.370	.153	.690 (.510; .931)	−2.421	.015*
Year built residence (Ref = before 1940)					
Year built = 1940–1970	.017	.154	1.017 (.751; 1.378)	.113	.909
Year built = 1971–2000	.079	.129	1.082 (.839; 1.396)	.612	.540
Year built = 2001 or later	.974	.159	2.650 (1.941; 3.624)	6.120	<.001***

house, after controlling the effects of other predictors in the model (OR = 3.331, $p < .05$).

Regarding number of males in household, the odds of a higher room temperature settings when only one man lived in house was 2.151 times greater than when there was no man in the household, given the effects of other predictors were held constant (OR = 2.151, $p < .001$). The odds of setting the room temperature on a higher degree when there were two men in the household was 1.924 times (OR= 1.924, $p < .01$) greater, and when there were 3 men in the household it was 2.342 times (OR = 2.342, $p < .01$) greater than when there was no man in the household, given the effects of other predictors were held constant.

The odds of setting the room temperature on a higher degree for those lived in detached houses was 0.635 times lower than for those lived in apartments, given the effects of other predictors were held constant (OR = 0.635, $p < .05$). The odds of being in higher categories of room temperature settings for those living in semi-detached houses was 0.630 times lower than those living in apartments (OR = 0.630, $p < .05$) and for those lived in terraced houses it was 0.690 times lower than those living in apartments, after controlling for the effects of the other variables (OR = 0.690, $p < .05$).

The odds of setting room temperature higher at day time for houses that were built in 2001 or later was 2.650 times greater than those built before 1940, given the effects of other predictors were held constant (OR = 2.650, $p < .001$).

3.4. *Explaining room temperature settings during night time*

Table 6 shows the result of Proportional Odds Model for room temperature settings during night time.[3] This model explained 15.8% of the variance in room temperature settings during night time. The log likelihood ratio Chi-Square test was $\chi^2_{(23)} = 214.75$, $p < .001$. Only biospheric values, egoistic values, the number of males in the household and the year of construction were significant predictors in this model. Stronger biospheric values were associated with lower room temperature settings, and stronger egoistic values, more males in the household and newer buildings were associated with higher room temperature settings. The odds of setting room temperature on a higher degree for one unit increase in biospheric values was 0.847 times lower, given the effects of other predictors are held constant (OR = 0.847, $p < .01$). The odds of setting room temperature on a higher degree for one unit increase in egoistic values was 1.097 times greater, after controlling for the effects of the other variables (OR= 1.097, $p < .05$). The odds of a higher room temperature settings when only one man lived in the household was 1.509 times greater than when there was no man in the household, given the effects of other predictors were held constant (OR = 1.509, $p < .05$). In terms of the year of construction, the odds of setting the room temperature on a higher degree at night time for houses built between 1971 and 2000 was 1.612 times greater (OR = 1.612, $p < .001$), and for those built in 2001 or later it was 5.889 times greater than those built before 1940 (OR = 5.889, $p < .001$), after controlling for the effects of the other variables.

4. Discussion

This paper examined whether room temperature settings of Dutch households that use gas as their main energy source for house heating during winter time could be explained by building characteristics, socio-demographic variables and values. Extending previous research [9,11–15,20], we found that building characteristics, socio-demographic and values are all three important and reliable predictors of room temperature settings, during day time and night time. In our view, this is an important novel contribution

[3] The Brant test of parallel regression assumption for room temperature at night time yields $\chi^2_{(161)} = 168.850$ ($p > .138$), indicating that the proportional odds assumptions for the model was upheld.

Table 6
Results for the Proportional Odds logistic regression Model (POM) for room temperature settings during night time including building characteristics, socio-demographic variables and values as predictor variables. $^{*}p < .05$; $^{**}p < .001$; $^{***}p < .001$.

Variable	Estimate	SE	OR (95%CI)	*t*-value	*p*-value
Age respondent	-.003	.004	.996 (.988; 1.004)	−0.846	.397
Biospheric values	-.165	.052	.847 (.764; .939)	−3.150	.002**
Egoistic values	.092	.043	1.097 (1.006; 1.195)	2.108	.035*
Altruistic values	.141	.054	1.014 (.910; 1.129)	.257	.797
Hedonic values	.077	.042	1.080 (.993; 1.174)	1.811	.070
Number of females (Ref = none)					
Number of females = 1	.309	.172	1.362 (.973; 1.913)	1.795	.073
Number of females = 2	.395	.231	1.485 (.944; 2.341)	1.709	.087
Number of females = 3	.137	.331	1.147 (.599; 2.196)	.415	.678
Number of females = 4 or more	.706	.487	2.027 (.782; 5.332)	1.450	.147
Number of males (Ref = none)					
Number of males = 1	.411	.162	1.509 (.099; 2.078)	2.534	.011*
Number of males = 2	.226	.214	1.254 (.823; 1.910)	1.055	.291
Number of males = 3	.150	.295	1.162 (.651; 2.077)	.510	.610
Number of males = 4 or more	.355	.526	1.426 (.508; 4.024)	.675	.500
Number of children (Ref = none)					
Number of children = 1	-.022	.184	.977 (.679; 1.402)	-.124	.901
Number of children = 2	.305	.224	1.356 (.874; 2.107)	1.360	.174
Number of children = 3	-.144	.360	.865 (.425; 1.747)	-.400	.689
Number of children = 4 or more	.611	.590	1.843 (.565; 5.790)	1.036	.300
Residence type (Ref = apartment)					
Detached house	.346	.185	1.414 (.983; 2.035)	1.870	.061
Semi-detached house	.113	.176	1.120 (.793; 1.584)	.645	.519
Terraced house	-.078	.150	.924 (.689; 1.242)	-.520	.603
Year built residence (Ref = before 1940)					
Year built = 1940–1970	.015	.157	1.016 (.745; 1.382)	.101	.919
Year built = 1971–2000	.477	.131	1.612 (1.247; 2.087)	3.641	<.001***
Year built = 2001 or later	1.773	.163	5.889 (4.277; 8.132)	10.821	<.001***

to the literature, suggesting that all three types of factors uniquely affect room temperature settings during both day time and night time.

In contrast to our expectation, results showed that residents of houses built in 2001 or later were during day time more than two times more likely and during night time nearly six times more likely to have higher room temperature settings than residents of houses built before 1940. In addition, higher room temperature settings during night time were about 1.6 times more likely for residents of houses built between 1971 and 2000 than residents of houses built before 1940. These findings are aligned the results reported by Hunt [16]; showing that people living in houses built after 1970 on average put the temperature higher than those living in houses built before 1914. Possible explanations are that central heating systems are more common in newer houses, and that those living in centrally heated buildings on average set indoor temperature higher than non-centrally heated buildings. Besides, newer buildings may have higher standards of insulation than older buildings [16]. Newer buildings may thus be better insulated than older buildings and therefore use less gas. As a consequence, people may be less motivated to save gas and potentially set room temperature in higher degree. Further research is needed to examine whether the level of insulation indeed plays a role in the effects we observed. These results are also aligned with earlier research suggesting that houses built from the 1940s use less energy for heating than those built from the 1980s perhaps because buildings constructed in 1980s were not designed to deliver comfort standards combined with energy-efficiency standards [14].

In terms of residence type, people living in detached houses, semi-detached houses and terraced houses tend to have lower room temperature settings during day time than those living in apartments. This may be because of the exposed wall areas of apartments which make them more thermally efficient, are more restricted than other residence types. This implies that residents feel colder and therefore need to set their room temperature higher. Interestingly, no differences were found in temperature settings during night for various resident types. Probably, temperature settings during night depend less on thermal efficiency of the exposed wall areas and desired comfort level than day time temperature settings.

As expected, room temperature settings during day time were explained by different socio-demographic variables. Specifically, older respondents were more likely to have higher temperature settings during day time. Similarly, the presence of more females and more males in households was associated with higher room temperature settings during day time. Specifically, setting high room temperature during day time for households with four or more females was more than three times greater than for households without any females. Similarly, when four or more males were present in a household, the likelihood of setting higher temperature during day time was more than two times greater than when no males were present in the household. This implies that temperature settings increase when more people are present in a household, both when the number of females and males in a household increases. This suggests that larger households are more likely to set higher temperature during day time. Future research could explore why larger household set the temperature higher.

In line with our expectations, the odds of setting a higher room temperature during day time were greater for females than for males. This can be explained by the fact that females are more sensitive to lower temperature and generally have a lower body temperature than males, and therefore females may feel less comfortable in colder environment than males [37–39]. These findings are not in line with some earlier studies that have found no gender differences in indoor temperature settings [21,22].

In contrast, socio-demographic variables did not significantly explain room temperature settings during night time, except when there was only one man in the household, room temperature settings were likely to be higher than when no man was present in the household. The differences in the effect of socio-demographic variables on observed room temperature settings at day time and night time suggest that room temperature settings at night time may be influenced by other factors. Dutch households may have developed a habit to set living room temperature lower during the night to save energy, and room temperature settings during night time less dependent on desired comfort level.

Results further showed that psychological values play an important role in explaining room temperature settings, particularly in day time room temperature settings. Specifically, stronger egoistic, altruistic and hedonic values were associated with higher room temperature settings during day time. People with strong egoistic values are more focused on their own interest and may therefore be less likely to care about the implications of their energy and gas use for the environment. People with strong altruistic orientation may set a high temperature in their room during day time as they care about others and pay relatively less attention to environmental consequences of their choices. People with strong hedonic values may set temperatures in their room during day time higher because they are motivated to feel comfortable. In contrast, stronger biospheric values were associated with a lower room temperature setting during day time as well as night time. This may be explained by people with stronger biospheric values being more aware and concerned about environmental problems, and being more motivated to reduce these problems, for example by adjusting their room temperature settings. Besides, we found that people with stronger egoistic values were more likely to set high temperature during night time. In sum, our findings indicate that psychological variables, notably values, are able to explain unique proportion of the variance in gas use behaviour, specifically room temperature settings, and are in line with previous studies that reveal that values play an important role in explaining household energy use (e.g. Refs. [9,40]. Specifically, the results show that gas-use related behaviour is most strongly positively related to egoistic values, hedonic values and altruistic values, and negatively with biospheric values. Our findings are mostly in line with previous studies: strong biospheric values are associated with energy saving behaviour, while strong hedonic values and egoistic values are associated with a higher energy use. Yet, our findings for altruistic values is in contrast to previous studies, as most studies show that stronger altruistic values relate to more pro-environmental action [41]. In our findings, reducing gas consumption could have negative implications for other (e.g. less comfort), while in many other studies, acting pro-environmental actions also benefit other people. In summary, these results highlight that values play a crucial role in the explanation of households' gas consumption behaviour.

In this study, the numbers of male respondents were nearly double the number of female respondents. One reason of a higher proportion of male respondents can be that males are more likely to respond to web-based questionnaire than females [42,43].

This study has important practical implications. These findings suggest that it would be important to target all three types of factors in policies aimed to reduce households' gas consumption behaviour**.** Values, more particularly biospheric values, play an important role in predicting room temperature settings. Targeting these values in interventions can encourage gas conservation behaviour. Besides, it seems important to consider the effects of insulation measures and energy efficiency retrofit strategies, to prevent that better insulation levels make people less careful about room temperature settings. Overall, our findings indicate that different routes can be followed in order to promote lower temperature settings. Strategies to promote gas savings would be particularly successful when they target values, particularly biospheric values and the year of construction of the houses as these are considered as the main predictors of room temperature settings during day time and night time. Importantly, our findings suggest that this is important from a policy perspective to encourage households to enhance reducing their gas consumption through not only considering socio-demographic characteristics, but also by targeting psychological variables such as values, as well as building characteristics. More importantly, socio-demographic characteristics cannot be easily changed while psychological factors and building characteristics can be more easily addressed in policy, making these a particular promising target for energy policy.

Future studies could include the effects of other building characteristics (e.g. insulation), psychological variables (e.g. environmental self-identity, attitudes and norms), and occupant behaviours (e.g. window-opening behaviours, house occupancy time) on the temperature settings in the living room during day time and night time in winter. Besides, future studies could investigate factors explaining the indoor temperature in different room types and along the hours of a day. Moreover, we suggest future studies should also include actual measures of gas use for heating (e.g. from smart meter reading). In addition, other factors affecting room temperature settings such as biological parameters and body temperature of household members might have significant impacts on room temperature settings that could be quantitatively assessed but their inclusion in a survey could be a challenging.

5. Conclusion

This paper aimed to assess the importance of building characteristics, socio-demographic variables and values in explaining room temperature settings for heating in Dutch residential building in winter that use gas for space heating during day time and night time. Extending previous research, we found that building characteristics, socio-demographics and values all explain unique variance in indoor temperature settings in the winter during day time and night time. More specifically, the year of construction, age of respondent, number of females in the household, number of males in the household and biospheric values were the most significant predictors of room temperature settings during day time. During night time, the year of construction and biospheric values played the most significant role in room temperature settings. Our findings have important practical implications and suggest that it would be important to target all three types of factors in policy aimed to reduce gas consumption, for example by lowering room temperature settings. Our findings indicate that there are different routes to promote lower temperature settings.

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Appendix A

The Proportional Odds Model (POM) is a class of generalised linear models used for an ordinal response on continuous or discrete covariates. The POM is a linear logistic model in which the intercepts depend on k, but the slops are all equal. Let suppose, the response is $Y = 1,\ 2,\ \ldots,\ K$ levels that have an inherent order. The associated probabilities are $\{\pi_1,\ \pi_2,\ \ldots,\ \pi_K\}$, and a cumulative probability of a response less than equal to k is:

$$P(Y \leq k) = \pi_1 + \ldots + \pi_k \tag{1}$$

The response categories are ordered, which suggest a certain relationship exists between them. To address this ordering, we focused on the cumulative logistic. The proportional odds or cumulative logit model is based on the logit of the dichotomization of $K-1$ cumulative probabilities across the K response levels:

$$\log\left(\frac{\Pr(Y \leq k)}{\Pr(Y > k)}\right) = \log\left(\frac{\pi_1 + \ldots + \pi_k}{\pi_{k+1} + \ldots + \pi_K}\right) \tag{2}$$

The POM assumes that each explanatory variable applies the same effect on each cumulative logit regardless of the cut-off k:

$$\log\left(\frac{\Pr(Y \leq k)}{\Pr(Y > k)}\right) = \alpha_k - X^T\beta \quad k = 1, \ldots, K-1 \tag{3}$$

Where X is a vector of explanatory variables and β is the corresponding set of regression parameters. The $\{\alpha_k\}$ parameters provide each cumulative logit (for each k) with its own intercept. The regression part the regression part $X^T\beta$ is independent of, so β has the same effect for each of the $K-1$ cumulative logits.

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